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ABSTRACT (Continue on reverse if necessary and identify by block number)

The attached report covers the first year of the project funded through Ohio State University Research Foundation. It represents the continuation and extension of work begun at the University of Kansas in 1987. Preliminary work to determine the temporal acuity of normal hearing listeners for spectrally-dynamic signals is complete. Pilot work on processing of frequency transitions in a "roving frequency" paradigm has been started; and work on listeners with cochlear hearing impairments has been added to the scope of work undertaken on the project.

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DEMODULATION PROCESSES IN AUDITORY PERCEPTION

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ANNUAL TECHNICAL REPORT

DEC. 1, 1988 - NOV. 30, 1989

Introduction

The overall goal of this project is to understand the ability of the human listener to extract information from complex, time-varying sounds such as speech, music or other environmentally important signals. Specifically, we are interested in the listener's ability to process modulations of frequency and amplitude which are thought to carry the information in such signals. In earlier work, we developed a signal-processing model of this human ability. The model calculates the Envelope-Weighted Average of Instantaneous Frequency (EWAIF) for such complex, time-varying signals. Our previous work has shown some success in using the EWAIF model to predict the pitch listeners perceive in such sounds, and to predict the discriminability of narrow bandwidth, complex, time-varying sounds.

While the original version of the EWAIF model processed the entire signal as one time unit, the more recent version has incorporated a brief time window to effect a "running" EWAIF model. Our experiments over the past year have been primarily directed toward determining the appropriate width of the time window. We characterize the experiments as assessing human auditory temporal acuity using spectrally-dynamic signals. Most previous work on auditory temporal acuity has been conducted using amplitude fluctuations (temporal modulation transfer functions, forward masking and gap detection, for example). Our tasks require listeners to extract information from signals that are moving across the spectrum, much as speech or musical sounds do.

The past year was divided into two areas of work. Experimental work initiated in fall 1 988 was continued throughout the year. STEP vs. GLIDE discrimination experiments were conducted with four very well practiced listeners for frequencies from 250 through 6 kHz. Effects of level of presentation from 30 through 70 dB SL were also investigated. Work begun at Kansas with R. Gerren was completed and analyzed. A series of experiments investigating the influence of envelope contour on FM-glide discrimination was conducted and a study of sinusoidal variation of frequency modulation about the linear trajectory was initiated by Y. Qi, the post-doctoral fellow selected to work on the project. This work was interrupted by the departure of Dr. Qi in July.

The second major part of the effort was devoted to modeling efforts. The PI was invited to spend spring and summer quarters as a visitor at the Applied Psychology Unit at Cambridge University. While there, he worked with Roy Patterson who has developed a model of auditory signal processing that grew from his efforts to understand the perception of pitch of complex tones and his interest in timbre perception. At the time of the invitation, the Patterson model had no dynamic signal processing capabilities. During the visit, Patterson revised and expanded the model in collaboration with J. Holdsworth to incorporate both spectral and temporal processing thought to be mediated in the auditory periphery. The PI's collaboration with Patterson has continued in an effort to combine the spectral dynamic capabilities of EWAIF with the features of the Patterson-Holdsworth model.

This work has been conducted in Room 322 Derby Hall on the Ohio State main campus in temporary lab facilities set-up because renovation of the department's new facilities on the West Campus was delayed. The move to Pressey Hall was carried out over the period from Dec. 15, 1989 through Jan 31, 1990. The new laboratory facility has three individual sound-treated rooms for the testing of listeners. We implemented a new response system using Radio Shack Color Computers (one in each booth) to display information for listeners and record responses. Each color computer is connected to the lab microcomputer using a Digicom multiple-port RS-232 inter-

face board. Because of the move, the laboratory was shut down for the six-week period from Dec. 15 to Jan 31.

Late in the fall term we acquired an Ariel DSP-16 digital signal processing subsystem for use in the generation of signals "on the fly", that is, complex, time-varying signals will be generated in real time. The DSP-16 system will enable us to implement the series of experiments described in the proposal that require the frequency of each transition to be randomized for each listening interval. In a procedure that is analogous to the "roving level" tasks in profile analysis, we expect to determine listeners' abilities to extract information from frequency modulated signals without confounding due to Pitch anchors. The first experiment in this series is to be reported in a presentation at the Penn State meeting of the Acoustical Society , May 22-25, 1990.

One series of experiments, not described in the proposal, but of interest to the PI, concerns the processing of STEP vs. GLIDE signals by listeners with sensori-neural hearing loss of cochlear origin. John Madden, doctoral candidate in Audiology has initiated this study as his dissertation work. Preliminary results will be reported at the Penn State meeting also.

List of research objectives and current status

1. Continue the STEP vs. GLIDE discrimination testing at other frequencies.

Testing of four well-practiced listeners was completed in the fall term. Results were reported at the St. Louis meeting of the Acoustical Society on Dec. 1, 1989. The temporal "threshold", that is the width of the step discriminable on 75% of forced-choice trials, falls at about 7 to 10 msec. for frequency transitions centered on 250 to 2000 Hz. Above 2 kHz, at 4- and 6 kHz, the temporal threshold approaches 20 msec. Results for frequencies below 2 kHz are remarkably stable over presentation levels from 30 to 70 dB SL, and transition rates of 2-, 4- and 8 Hz/msec. Because of concerns about small spectral differences between the linear glide signal and the original step signal, Y. Qi developed a program to synthesize step signals with "rounded" corners, that is, more gradual frequency transitions from one frequency in the step to the next. Test of rounded-corner step transitions vs. glide discrimination showed no significant differences in temporal thresholds. After several false starts, it does appear that a paper for submission to the Journal of the Acoustical Society will be forthcoming over the spring and summer terms.

2. Implement a multiple-band version of the EWAIF model to handle wide bandwidth sounds.

The visit to Roy Patterson's laboratory was designed to get this effort underway. Patterson's modeling efforts were in "high gear" at the time of the PI's arrival at Cambridge. The original Pulse Ribbon model has been broadened and extended to produce the Auditory Sensation Model which seeks to reproduce the effects of peripheral filtering, nonlinearity, lateral interactions and short-term adaptation. Further, the model implements a triggered, quantized temporal integration process to produce a sequence of pictures of simulated neural outputs which have dynamic properties that follow the sensations experienced by normal listeners. Complex sounds without frequency transitions produce stable images on the display; spectrally-dynamic sounds produce moving images that mimic the movement perceived by the listener. With the aid of A. Krishnamurthy, we hope to implement EWAIF-like processes onto the Patterson-Holdsworth model output to reduce the data rate to a more manageable level. Currently, the P-H model output is in the form of moving pictures that are displayed on workstation displays. Krishnamurthy has applied for a summer faculty position with the Bio-Communications Lab at Wright-Patterson AFB for summer 1990. If that application is funded, he will work on the EWAIF stage of the P-H model at the Bio-Communications Lab over the summer.

3. Complete the single-step vs. glide discrimination experiments.

This series of experiments, begun in collaboration with R. Gerren at Kansas were completed early in spring 1989. Gerren visited Ohio State in Nov. 1989 to finish analysis of the data and to begin work on writing a paper for submission to the journal.

4. FM transitions with amplitude contours.

Preliminary work on this phase of the proposed work was completed in Nov. 1989. The three well-practiced listeners were much better at the task than anticipated. Envelope changes of very small proportions were easily detected because of the pitch difference imposed on the signals. This work will serve as base line values for later work done in the random starting frequency paradigm. That work will be done after the glide direction discrimination work (described below) is completed.

5. Glide direction discrimination

Work on this series of experiments has just begun. The Ariel DSP-16 board will produce frequency modulated signals (linear glides) that begin on randomly selected starting frequencies. Randomization of starting frequency will render the pitch differences heard in such signals unreliable cues for determining which signal is moving in the opposite direction. We expect to collect preliminary data in spring quarter and to present it at the Acoustical Society meeting in May. This work must be completed before later work on transition slope discrimination, envelope contour effects and the whole series described as "source-filter" signal experiments can be initiated.

Participating Professionals

Lawrence L. Feth, Ph.D.	Principal Investigator
Ashok K. Krishnamurthy, Ph.D.	Co-Investigator
Yingyong Qi, Ph.D.	Post-doctoral Fellow (to July 1, 1989)
Mary E. Neill, B.A.	Graduate Research Asst.
John B. Madden, M.A.	Graduate Research Asst. (fr. Jan 1, 1990)
Chienyea Hsu, M.A.	Graduate Research Asst. (fr. Jan 1, 1990)

Publications and Presentations

Auditory temporal Acuity for dynamic signals. L. L. Feth, M. E. Neill and A.K. Krishnamurthy. [Abstract: *J. Acoust. Soc. Amer.*, 86, p. S122 (1989)] Presentation to the Acoustical Society meeting Nov. 1989, St. Louis.

Discrimination of frequency-glide direction. M. E. Neill and L. L. Feth to be presented at the Acoustical Society meeting May 1990, Penn State.

Auditory temporal acuity in hearing-impaired listeners for frequency-modulated signals. J. P. Madden and L. L. Feth to be presented at the Acoustical Society meeting May 1990, Penn State.

The EWAIF model and demodulation processes in auditory perception.

Presented by L. L. Feth to:

The Chaucer Club (research seminar) at the Applied Psychology Unit, Cambridge University, U.K. April 1989.
Research Forum of the Institute of Hearing Research, Nottingham England, May 1989.
Informal Meeting on Models of Auditory Perception Experimental Psychology Department Cambridge University July 1989.

Patents and Inventions

No patentable inventions have resulted from this research.

Statements

The unexpected departure of YY Qi in July 1989 has had a temporary negative effect on the progress of the research planned for this project. Dr. Qi's experience in modeling and in digital signal processing will be difficult to replace. Dr. Krishnamurthy's continued participation in the work will help to continue the modeling work planned with Dr. Qi. C. Hsu, a doctoral student in Electrical Engineering with interests in signal processing will help to continue the development of special analysis and synthesis programs using the Ariel DSP-16 signal processing board.

Our work on temporal acuity with hearing impaired listeners was not planned in the original proposal. It comes at a time when several other labs have indicated an interest in applying these techniques to the study of impaired listeners. Since J. Madden has an interest in the area, his dissertation work will allow this project to broaden. Further work with impaired listeners will be funded from NIH or other appropriate sources after Madden finishes his degree work and assumes a faculty position. There is a strong likelihood that he will be employed at either Kent State or Cleveland State and that a collaboration with the PI will be possible on this line of work.